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Measuring low-PRF pulsed signals with  
a standard HP 8510B vector network  
analyzer within milliseconds

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Report no. : FEL-90-B238  
Title : Measuring low-PRF pulsed signals with a standard HP  
8510B vector network analyzer within milliseconds

Author(s) : Ir. H.J. Visser  
Institute : TNO Physics and Electronics Laboratory  
Date : August 1990

NDRO no. : -  
No. in pow '90 : 710.2

Research supervised by : Ir. J.G. van Hezewijk  
Research carried out by : Ir. H.J. Visser

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#### ABSTRACT (UNCLASSIFIED)

This report describes how a Hewlett Packard HP 8510B vector network analyzer with a non-pulsed test set can be used for measuring pulsed-RF signals with a low pulse repetition frequency within milliseconds, by making use of the external trigger facility. This measurement configuration is derived after an analysis of the signal flow through the receiver of the network analyzer. Although the measurement method is derived for a specific pulsed-RF signal (carrier: 5.3 GHz; pulse repetition frequency: 3.5 kHz; pulse width: 12.8  $\mu$ s) and meant for use in a near-field measurement facility, its applicability is more general. It will not be possible to perform pulse profile measurements. The desired and attained measurement specifications are:

Desired specifications:	Attained specifications:
Dynamic range : $\geq 40$ dB;	50 dB;
ampl. accuracy : $\pm 0.3$ dB;	$\pm 0.10$ dB;
phase accuracy : $\pm 3.0^\circ$ ;	$\pm 1.0^\circ$ ;
measurement time : $< 10$ ms.	1.14 ms.

Rapport no. : FEL-90-B238  
Titel : Het meten van lage-PRF gepulste signalen met een  
standaard HP 8510B vector network analyzer binnen  
enkele milliseconden

Auteur(s) : Ir. H.J. Visser  
Instituut : Fysisch en Elektronisch Laboratorium TNO  
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Onderzoek uitgevoerd o.l.v. : Ir. J.G. van Hezewijk  
Onderzoek uitgevoerd door : Ir. H.J. Visser

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#### SAMENVATTING (ONGERUBRICEERD)

Dit rapport beschrijft hoe een Hewlett Packard HP 8510B vector network analyzer met een niet-gepulste test set gebruikt kan worden voor het meten van gepulste signalen met een lage puls repetitie frequentie binnen enkele milliseconden, door gebruik te maken van de externe trigger mogelijkheden. Deze meet-configuratie is ontwikkeld na analyse van de signaaldoorgang door de ontvanger van de network analyzer. Hoewel de meetmethode is afgeleid voor een specifiek gepulst signaal (draaggolf: 5,3 GHz; puls repetitie frequentie: 3,5 kHz; puls breedte: 12,8  $\mu$ s) en bedoeld is voor gebruik in een nabije-veld meetfaciliteit, is de methode algemeen toepasbaar. Het is niet mogelijk puls profiel metingen te verrichten. De vereiste en bereikte meetspecificaties zijn:

Vereiste specificaties:		Bereikte specificaties:
Dynamisch bereik	: $\geq 40$ dB;	50 dB;
ampl. nauwkeurigh.	: $\pm 0.3$ dB;	$\pm 0.10$ dB;
fase nauwkeurigh.	: $\pm 3.0^\circ$ ;	$\pm 1.0^\circ$ ;
meettijd	: $< 10$ ms.	1.14 ms.

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## 1 INTRODUCTION

Vector network measurement has been, and is, used in characterizing microwave devices. Until now, vector network analyzers (NWA) were designed to operate with a continuous microwave (CW) driving signal. However, an increasingly important class of microwave devices have a requirement not normally associated with standard (CW) vector network measurement. These devices must be characterized under pulsed-RF conditions.

### 1.1 Pulsed measurements

One such a device is an active phased array antenna designed for the PHARUS project. PHARUS stands for *Phased Array Universal SAR*. This antenna must be characterized under pulsed-RF conditions, because:

- In this way, the antenna will be measured under operational conditions;
- the active components will behave differently under CW conditions;
- the antenna operates at such a high peak power, that characterization using a CW measurement system would destroy the antenna.

Although vector network analyzers designed for measuring pulsed-RF signals are beginning to become available, like the Hewlett Packard HP 8510B with option 008 and the Wiltron 360-PS20, this report describes how a 'standard' HP 8510B can be used for measuring pulsed-RF signals, as long as one is not interested in pulse profile measurements.

## 1.2 Organization of the report

The organization of the report is as follows: After the measurement specifications are given in chapter 2, in chapter 3 the passing of a pulse signal through the receiver of the NWA is treated and following that, measurement configurations for measuring pulsed signals, as proposed by Hewlett Packard, are discussed. Then, in chapter 4, results of internally triggered measurements of pulsed signals in a CW measurement configuration are given, followed by a discussion in chapter 5 of a new method for measuring pulsed signals as if it are CW signals, by making use of the external trigger facility of the NWA. Finally, a description is given of experiments carried out with this new measurement method and in chapter 6 the results are compared with the results obtained with the internally triggered CW measurement configuration.

## 2 MEASUREMENT SPECIFICATIONS

The characteristics of the PHARUS-antenna will be measured in the FEL-TNO planar near-field measurement facility. Both antenna and near-field measurement facility impose restrictions on the allowable measurement-times. These restrictions will be discussed in detail in the following.

### 2.1 PHARUS-antenna

As mentioned before, the PHARUS-antenna will be operated under pulsed-RF conditions. The pulse signal is shown in figure 1.

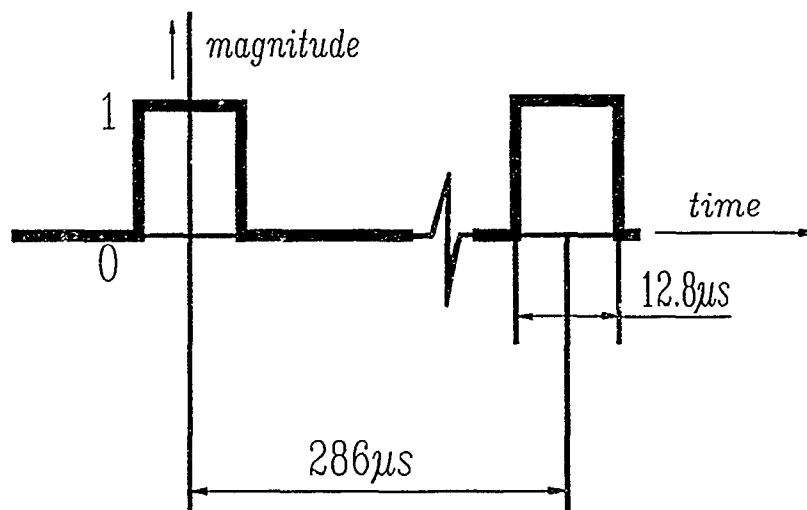


Fig. 1: PHARUS pulse signal

The carrier frequency will be 5.3 GHz (C-band). The Pulse Repetition Frequency (PRF) is 3500 Hz and the pulse-width  $\tau$  is 12.8  $\mu$ s [1]. So the duty-cycle is 4.48 %.

## 2.2 Near-field measurement facility

Figure 2 shows a planar near-field measurement configuration [2, p.6].

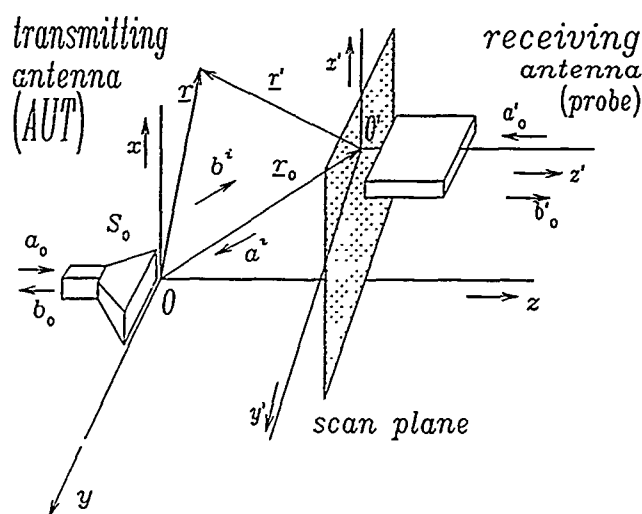


Fig.2: Transmission system set-up for planar near-field measurement

The Antenna Under Test (AUT) can be operated as a transmitting antenna as well as a receiving antenna [3]. The aperture of the probe is moved over a planar surface, parallel to the aperture of the AUT, called the scan plane. In case of a transmitting AUT, samples of the electric field (amplitude and phase), generated by the AUT, are taken in equidistant points that are arranged in a rectangular grid. With the obtained near-field data, far-field characteristics can be calculated.

### 2.3 Desired specifications

The measurement times are dictated by probe velocity, carrier frequency, dimensions of the scan plane and the number of multiplexed measurements. The rectangular grid of sample points is shown in figure 3.

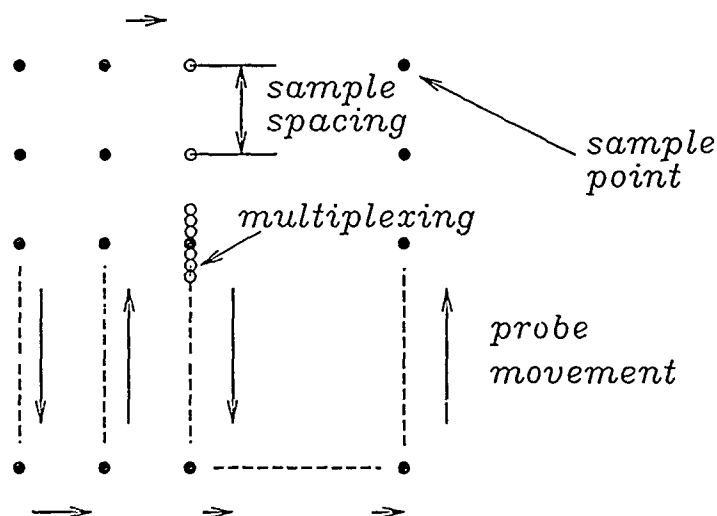


Fig.3: Planar near-field measurement grid

It is common practice to space the sample points one third of a wavelength apart [4, p.607; 5, p.259]. The dimensions of the scan plane are 3 m x 3 m. With a carrier frequency of 5.3 GHz, the sample points are spaced 1.89 cm apart. When using the probe at its maximum velocity, i.e. 4 cm/s, one row of 3 m will be completed in 75 s (samples will be taken while moving the probe). In that time 158 sample points are passed by and the time elapsed between two adjacent points is 0.47 s.

Since one scan session will last about 3 hours and 17 minutes ( $158 \times 75$  s) and since for a phased array antenna many radiation patterns need to be measured (e.g. for different scan angles), it is desirable to combine measurement of different radiation patterns in one scan session, called multiplexing. Supposing a multiplexing of 10 measurements, of which the

sample points need to be distributed around the the sample points as shown in figure 3, and taking into account some switching overhead, it is desired that measurement of amplitude and phase will take less than, say, 10 ms.

In order to obtain precise far-field characteristics, the receiver of the measurement system must accurately measure amplitude and phase of an RF-signal over a dynamic range of at least 40 dB [5, p.256; 6, p.32; 7, p.32; 8, p.8]. For amplitudes ranging between 0 and -40 dB, a fluctuation of  $\pm 0.3$  dB in amplitude and  $\pm 3.0^\circ$  in phase is allowed [5, p.256; 7, p.170; 9, p.839].

The desired NWA specifications are summarized below:

Dynamic range	: $\geq 40$ dB;
amplitude accuracy	: $\pm 0.3$ dB;
phase accuracy	: $\pm 3.0^\circ$ ;
measurement time	: $< 10$ ms.

## 3 PULSE SIGNALS AND THE HP 8510B

To understand the problems involved with measuring pulsed-RF signals with a NWA, the passing of a pulsed-RF signal through the receiver of the HP 8510B will be discussed. It will appear that the easiest approach to understanding the characteristics of the receiver is to look into the frequency domain. When the functioning of the receiver is understood, measurement configurations can be developed.

## 3.1 Pulsed-RF signal passing the receiver

The block diagram of the HP 8510B NWA receiver is shown in figure 4.

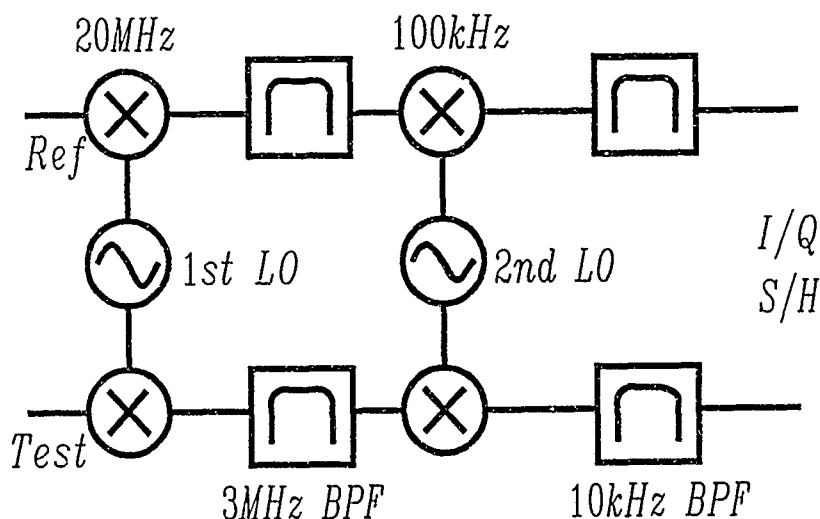


Fig. 4: Receiver block diagram

The receiver is a double conversion superheterodyne with a 10 kHz wide BandPass Filter (BPF) in the second IF. This 10 kHz filter is the component that dictates how the HP 8510B responds to pulsed signals.

For the pulsed-RF test signal the PHARUS signal is taken, of which the characteristics are summarized below and a graphical representation is given in figure 5.

Carrier frequency : 5.3 GHz;  
pulse repetition frequency : 3.5 kHz;  
pulse width : 12.8  $\mu$ s;  
duty cycle : 4.48 %.

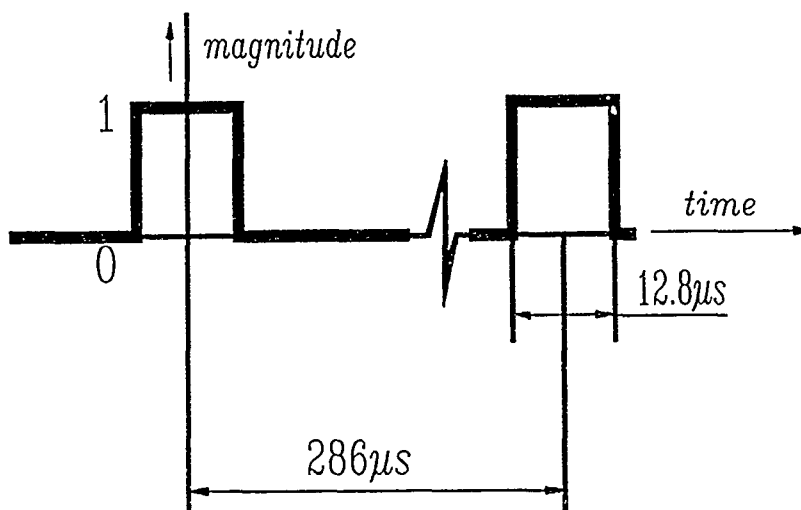


Fig. 5: PHARUS pulse signal

The test signal can be written in the time domain as:

$$x_s(t) = x(t) \cdot s(t) \quad (1)$$

with  $x(t)$  the 5.3 GHz sinusoidal carrier signal and [11, pp.507-510]:

$$s(t) = C_0 + \sum_{n=1}^{\infty} 2C_n \cos(n2\pi f_{PRF}t) \quad (2)$$

$$C_0 = \tau/T_{PRF} = f_{PRF} \cdot \tau \quad (3)$$

$$C_n = f_{PRF} \cdot \tau \cdot \text{sinc}[nf_{PRF}\tau] \quad 1) \quad (4)$$

The frequency domain representation of  $x_s(t)$  is given by:

$$X_s(f) = C_0 X(f) + \sum_{\substack{n=-\infty \\ n \neq 0}}^{\infty} C_n X(f - nf_{PRF}) \quad (5)$$

in which  $X(f)$  is the frequency domain representation of the 5.3 GHz carrier  $x(t)$ . The frequency domain representation (5) is shown in figure 6.

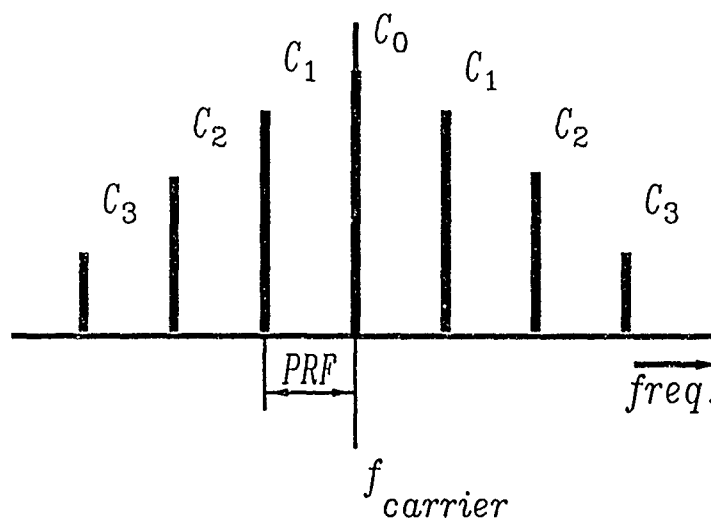


Fig. 6: Frequency domain representation PHARUS pulse signal

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1)  $\text{sinc}(x) = \sin(\pi x)/\pi x$

The receiver shifts the frequency spectrum as shown in figure 6 in such a way that the central frequency (with amplitude coefficient  $C_0$ ) is equal to the frequency of the second Local Oscillator (LO). Figure 7 shows the signal representation - in the frequency domain - of the signal as present in the receiver *before* the 10 kHz BPF. The effect of the BPF is illustrated - in the frequency domain - in the same figure (dashed line).

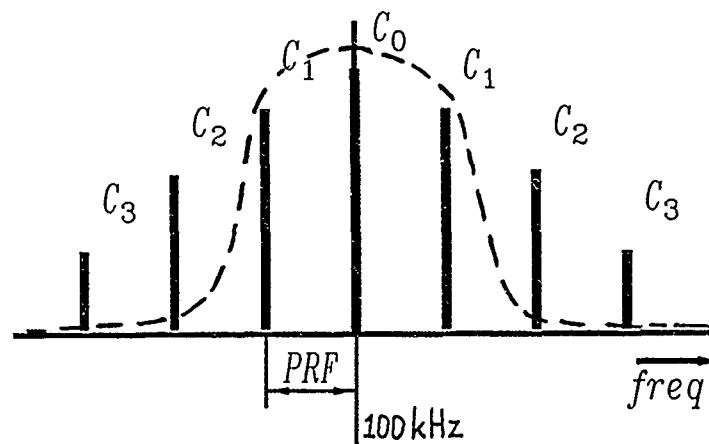


Fig. 7: Effect of bandpass filtering

The frequency domain signal representation at the output of the BPF is given by:

$$\begin{aligned}
 X_{s_{out}}(f) = & \alpha_0 C_0 X(f + f_{LO1} - f_{LO2}) + \\
 & + \sum_{\substack{n=-\infty \\ n \neq 0}}^{\infty} \alpha_n C_n X(f + f_{LO1} - f_{LO2} - n f_{PRF})
 \end{aligned} \tag{6}$$

with  $\alpha_n$  ( $n = \dots, -2, -1, 0, 1, 2, \dots$ ) depending on the filter characteristics.

If, for the sake of simplicity, an ideal 10 kHz BPF is assumed, that is:

$$\alpha_n = \begin{cases} 1 & \text{for } n = -1, 0, 1 \\ 0 & \text{else} \end{cases}$$

for a pulse repetition frequency of 3.5 kHz, the time domain representation of the BPF-output is given by:

$$x_{\text{out}}(t) = (1/8) \cos(2\pi \cdot 100 \cdot 10^3 \cdot t) \cdot \\ \cdot [2C_1 \cos(2\pi \cdot 3.5 \cdot 10^3 \cdot t) + C_0] \quad (7)$$

Time and frequency domain representations and bandpass filtering (assuming an ideal 10 kHz BPF) are shown in figure 8.

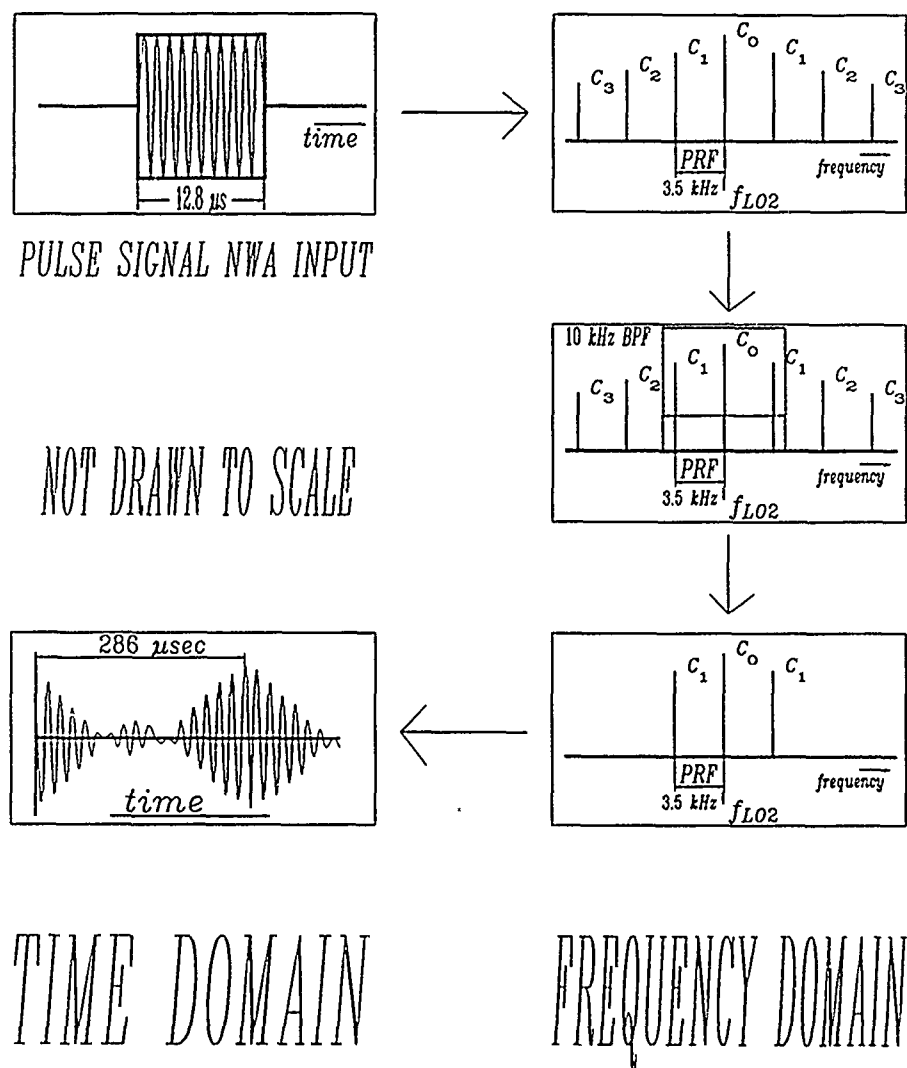


Fig. 8: Test signal passing through the HP 8510B receiver

Besides the wanted frequency of 100 kHz (see figure 4), two other frequency components are also present in the output signal, causing the output signal to fluctuate rapidly with a period of 286  $\mu$ s. This signal hardly resembles the sinusoidal signal needed for amplitude and phase measurement.

### 3.2 HP measurement configurations

Hewlett Packard offers two solutions for measuring with pulsed-RF signals with a standard HP 8510B [10]. The bandpass filter's characteristics divide the measurement into two categories: PRF's greater than 30 kHz and PRF's less than 30 kHz.

#### 3.2.1 PRF's greater than 30 kHz

For PRF's greater than 30 kHz, the BPF only passes the center spectral line (carrier) of the pulsed-RF spectrum and so the receiver measures the pulsed-RF signal as if it were a CW signal in a non-pulsed network analyzer configuration.

The configuration (figure 9) for making pulsed vector network measurements with a PRF of greater than 30 kHz is very similar to the standard measurement configuration. A difference is the coupler at the output of the source. This coupler supplies a CW signal to the HP 8510B for phase locking the system, as the phase lock loop cannot lock to a pulsed signal.

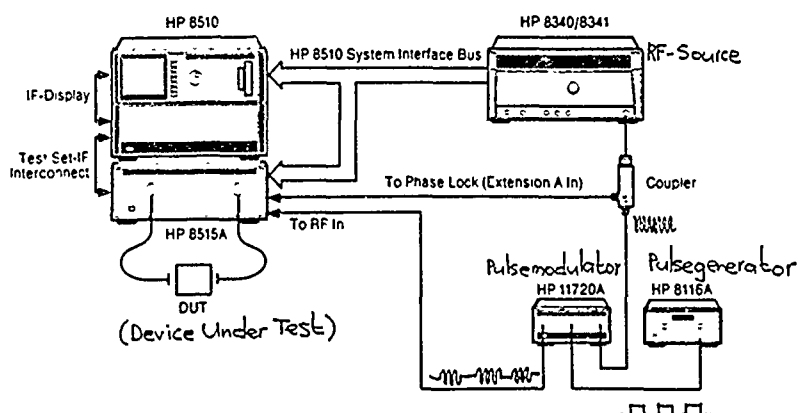


Fig. 9: Pulsed-RF configuration for PRF's > 30 kHz

### 3.2.2 PRF's less than 30 kHz

For PRF's less than 30 kHz, the IF signal will include not only the centre spectral line but also the other spectral lines that enter the bandwidth of the filter. These additional spectral lines result in magnitude variations in the signal as a function of time (the pulses will appear in the IF). Since the receiver takes a ratio of the measurement and test channels, the magnitude and phase shift through the device is still provided. However, the receiver needs the added capability of providing a synchronization signal that can trigger the measurement at the peak of these IF pulses. This will then maximize the signal-to-noise ratio, thus maximizing the available dynamic range and accuracy.

The HP measurement configuration (as shown in figure 10) looks very much like the one shown in figure 9. The measurement configuration of figure 9 is extended with a connection between pulse modulator and external trigger input of the NWA.

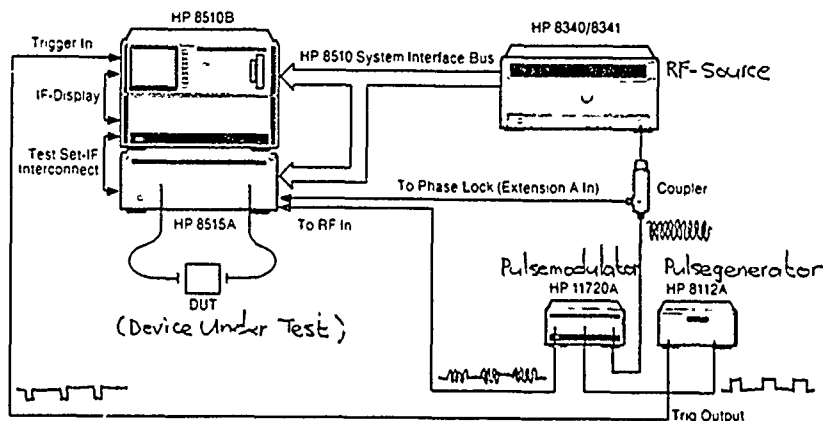


Fig. 10: Pulsed-RF configuration for PRF's < 30 kHz

In the above configuration, the HP 8510B will be used in ramp sweep mode [10] with the frequency sweep set to the minimum value. The HP 8510B

will use the external trigger to update the measurement, instead of the sweep ramp.

This measurement method, proposed by Hewlett Packard, is not suited for measuring the PHARUS-antenna in the FEL-TNO near-field measurement facility for two reasons: First, experiments with the HP 8510B in ramp sweep mode have shown that each measurement of amplitude and phase lasts about one half of a second (see appendix A), which is far too much (see paragraph 2.3) and second, because of the ramp sweep mode, the carrier frequency is too unstable for use in near-field measurement (one scan-session will last more than three hours). So another way of measurement must be found.

#### 4 INTERNALLY TRIGGERED MEASUREMENT OF PULSED-RF SIGNALS IN A CW MEASUREMENT CONFIGURATION

Although, in principle, measurement of the PHARUS-low-PRF pulsed signal in a non-pulsed network analyzer configuration is not the obvious way for measuring this signal (see figure 8), internally triggered measurements in a CW measurement configuration are still carried out since for the moment there is no other way left. By means of averaging, the desired dynamic range and accuracy are attained, at the cost of time 2). Measurements are carried out with a CW reference signal and with a pulsed reference signal. A CW signal is always provided for phase locking the system.

##### 4.1 CW reference signal

The measurement configuration is shown in figure 11.

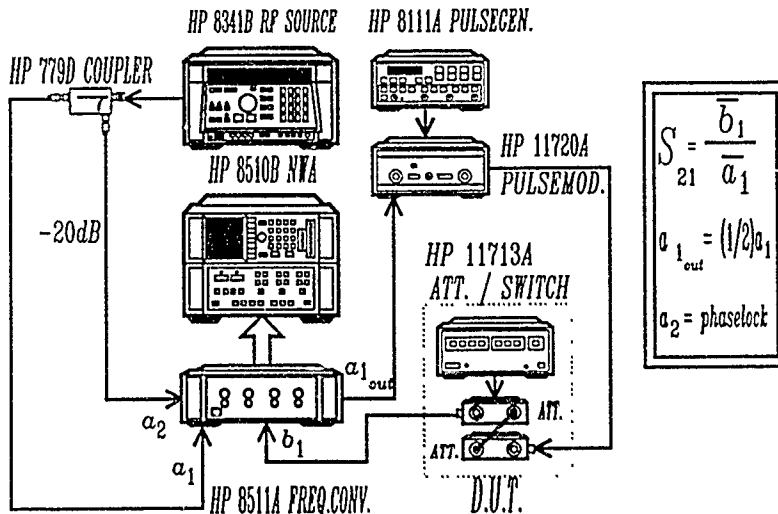


Fig. 11: Measurement configuration; CW reference signal

2) The measurement time increases with  $(200 \mu s \times \text{averaging factor})$  [12, p.27].

With the aid of a step-attenuator, amplitude- and phase-fluctuations as function of attenuation level are measured. Amplitude- and phase-fluctuation are indicated in figure 12. The results are shown in figure 13. Without averaging it is not possible to get reliable results. More information is given in appendix B.

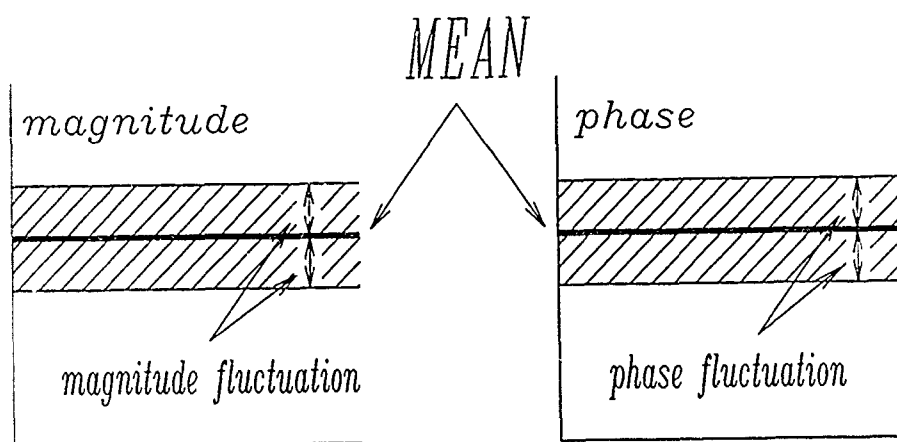
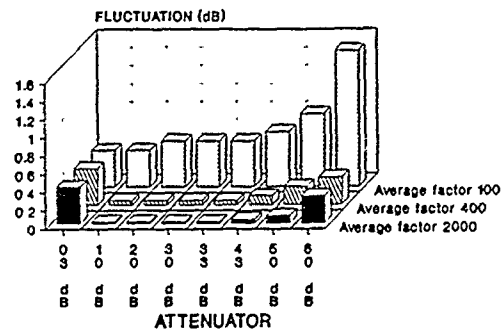


Fig.12: Amplitude- and phase-fluctuation

### AMPLITUDE FLUCTUATION

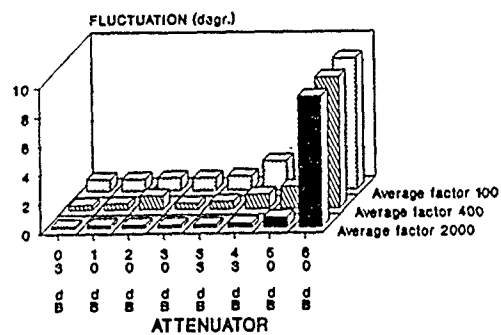
measurement pulsed signal, CW reference



a) Amplitude fluctuation

### PHASE FLUCTUATION

measurement pulsed signal, CW reference



b) Phase fluctuation

Fig. 13: Amplitude- and phase-fluctuation; measurement results

Figure 13 shows that an error has occurred measuring the amplitude-fluctuation at an attenuation level of 3 dB and for the phase-

fluctuation at an attenuation level of 60 dB. In spite of these erroneous measurements, figure 13 shows that the desired accuracy and dynamic range is attained for an averaging factor of 400.

#### 4.2 Pulsed-RF reference signal

The reason for not using a CW reference signal but pulsing *both* reference and test signal is explained in [10]:

- Removal of effects of the modulator itself;
- removal of the offset caused by the pulse desensitization (magnitude decrease caused by the loss of energy in the sidebands);
- noise reduction.

The measurement configuration is given in figure 14; the measurement results are shown in figure 15. More information is given in appendix C.

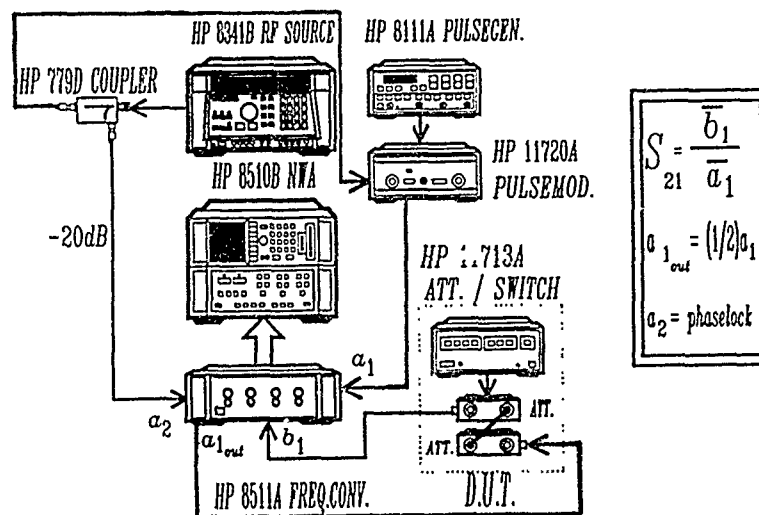
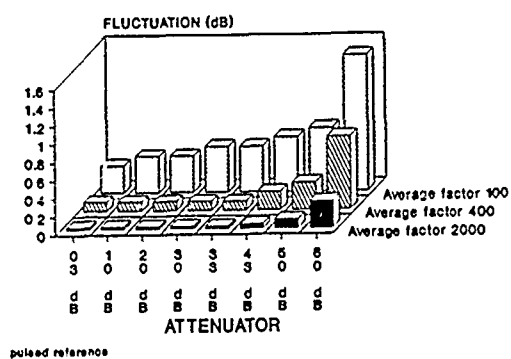


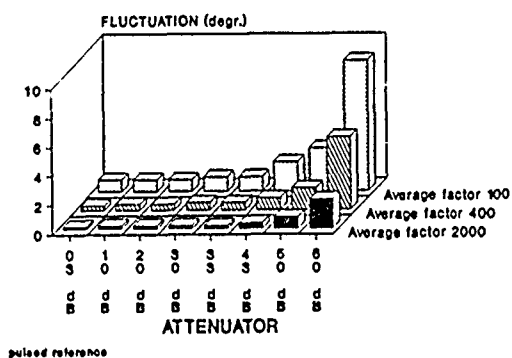
Fig. 14: Measurement configuration; pulsed-RF reference signal

### AMPLITUDE FLUCTUATION measurement pulsed signal



a - Amplitude fluctuation

### PHASE FLUCTUATION measurement pulsed signal



b - Phase fluctuation

Fig. 15: Amplitude- and phase-fluctuation; measurement results

The measurements give the same results as those found in paragraph 4.1 (see figure 13, 15; appendix B, C). Accuracy and dynamic range are attained for an averaging factor of 400.

Every averaging adds  $200\ \mu\text{s}$  to the measurement time [12, p.27]. So the measurement time would be more than  $400 * 200\ \mu\text{s} = 80\ \text{ms}$ . This lasts too long, so another way for measuring pulsed-RF signals must be found. The fact that measurement results obtained with a CW reference signal are the same as those obtained with a pulsed-RF reference signal, is caused by the use of a HP 8511A frequency convertor instead of a HP 8515A test set that is discussed in [10]. The HP 8511A frequency convertor is much less noise-sensitive than the HP 8515A test set. This is caused by the low insertion loss of the frequency convertor. Since the pulse width is very small ( $12.8\ \mu\text{s}$ ), use of the HP 8511A is recommended. If the pulse widths of the RF pulses are longer than  $200\ \mu\text{s}$ , the IF signal will rise to its steady state value [10, p.3]. If the pulse is narrower than  $200\ \mu\text{s}$ , the pulse will not rise to its steady state value. Although the level does not reach the steady state level, it may reach a level that can be used to make a valid measurement. As a guideline, the measurement level falls off 6 dB for every octave decrease in pulse width below  $200\ \mu\text{s}$  [10, p.3].

## 5 A METHOD FOR MEASURING LOW-PRF PULSED SIGNALS

When looking at figure 8 of paragraph 3.1, possible solutions for measuring the PHARUS pulsed-RF signal as if it is a CW signal come up. It is obvious that the problems are caused by the width of the BPF in the second IF. Three possible measurement solutions are:

- Additional filtering after the 10 kHz BPF;
- using a NWA with a smaller BPF;
- triggering with a frequency equal to the Pulse Repetition Frequency.

Of the above proposals for measurement, the first one is dropped since the output of the BPF is not externally available.

## 5.1 Using a NWA with a smaller BPF

If the IF bandpass filter would have a smaller bandwidth, say about 100 Hz, it would be possible to measure the PHARUS pulsed-RF signal as if it is a CW signal, as is indicated in figure 16. Wiltron offers a vector network analyzer (Wiltron 360) provided with an adjustable IF bandwidth: 10 kHz, 1 kHz and 100 Hz. This NWA is used with a non-pulsed test set.

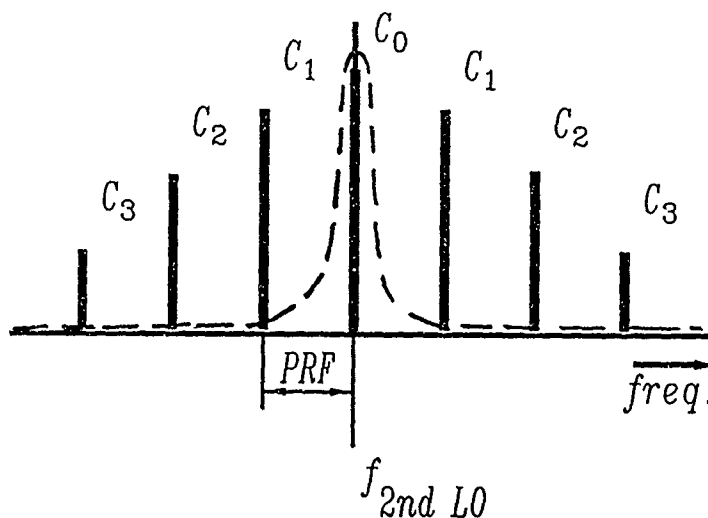


Fig. 16: Effect of small-bandwidth-BPF on PHARUS-signal

Measurements, however, of amplitude- and phase-fluctuations with this NWA with IF bandwidth of 100 Hz, showed that the analyzer does not behave in the way expected. The measurements are treated in detail in appendix D. The measurement results are given in figure 17.

### AMPL. & PHASE FLUCTUATION WILTRON 360 measurements

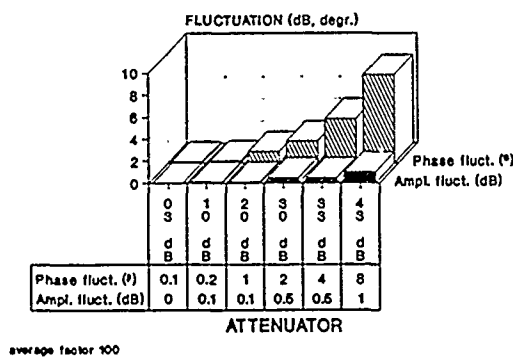


Fig. 17: Amplitude- and phase-fluctuation; pulsed-RF reference

The 100 Hz IF filter is not ideal - it has a smooth fall off - and passes more than one frequency component. 3) This method is in principle possible, but it needs a sharp fall off filter. Note, in figure 17, that an averaging factor of 100 is applied.

3) In the Wiltron 360-PS20 pulsed NWA, a filter with a sharp fall off is present. For measurement results, see appendix E [13].

## 5.2 Using the HP 8510B external trigger facility

Looking at the (calculated) signal at the output of the 10 kHz BPF (figure 18), a way can be found for measuring the PHARUS pulsed-RF signal.

### output 10kHz BPF, time domain

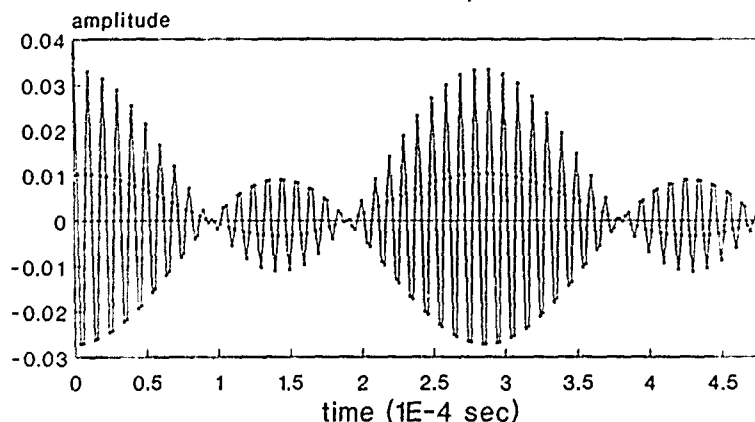


Fig. 18: Output of 10 kHz BPF

Regardless of the bandwidth of the IF filter, the filter-output is always periodic with period  $286 \mu\text{s}$ , corresponding with the lowest frequency component present, e.i. the PRF of 3.5 kHz (see equation(7); paragraph 3.1).

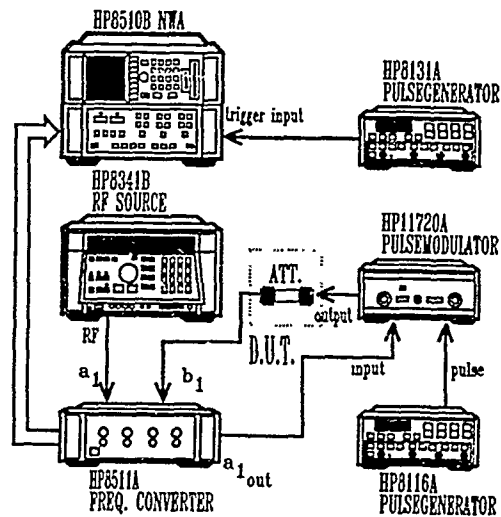
So, if it is possible to trigger the NWA for measurement every  $286 \mu\text{s}$  or multiple of  $286 \mu\text{s}$ , the effects caused by the sidebands still present in the frequency spectrum (fluctuations) are eliminated and the signal is measured as if it is a CW signal. In the Fast CW mode, data is available approximately 1 millisecond after the (external) trigger pulse is received [12, p.24], so it looks that a way of measurement is found that satisfies all measurement specifications.

## 6 EXTERNALLY TRIGGERED MEASUREMENTS

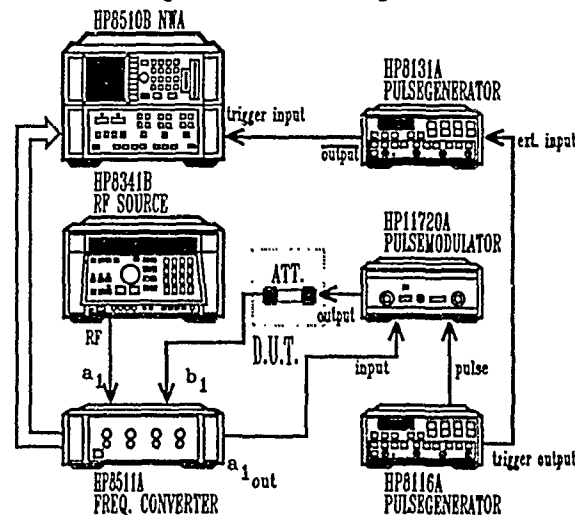
When measuring the PHARUS pulsed-RF signal using the HP 8510B external trigger facility, two pulsed signals are present in the measurement set-up: The PHARUS signal, that needs to be measured, and the trigger signal, extracted from the PHARUS-signal and used to externally trigger the HP 8510B. The HP 8510B will take data on a negative-going TTL trigger pulse (pulse width: 1  $\mu$ s minimum) [12, p.27].

### 6.1 Measurement configurations

The first experiments were carried out with two pulse generators running free, of which one was used to externally trigger the HP 8510B (see figure 19a), resulting in a fluctuating signal not at all satisfying the desired accuracy. Experiments with two synchronized pulse generators without delaying the trigger signal (see figure 19b) resulted in non-reproducible measurements. So it appears that synchronization is of paramount importance.



a) Pulse generators running free



b) Pulse generators synchronized

Fig. 19: Measurement configurations; externally triggered

In the measurement configuration shown in figure 20, the trigger signal is extracted from the pulse signal (3.5 kHz) and delayed, thus providing a good synchronization. When the HP 8510B is busy, trigger signals are

ignored, so measurements or data transport are not interrupted and measurements are carried out for multiples of 286  $\mu$ s.

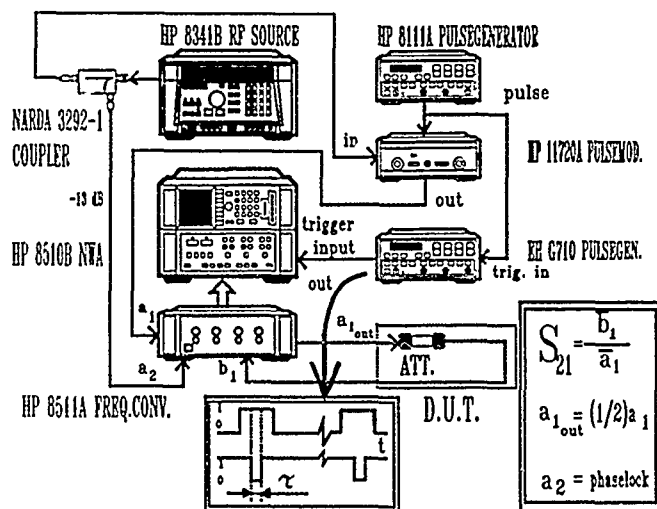


Fig. 20: Low-PRF measurement configuration

With a delay, the trigger pulse can be shifted into the RF pulse to maximize the measured power. Measurements will then be taken when the received field is maximal (see figure 8).

In order to get accurate measurement results, the pulse-form must not be disturbed. For certainty the pulse-form can be monitored during measurement.

Measurement results are discussed in the next paragraph.

## 6.2 Measurement results

Measured again are amplitude- and phase-fluctuations versus attenuation level. The results are shown in figure 21.

### AMPL. & PHASE FLUCTUATION externally triggered measurements

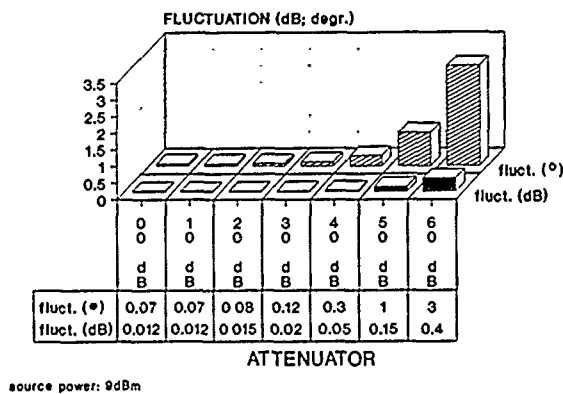


Fig. 21: Low-PRF measurement results

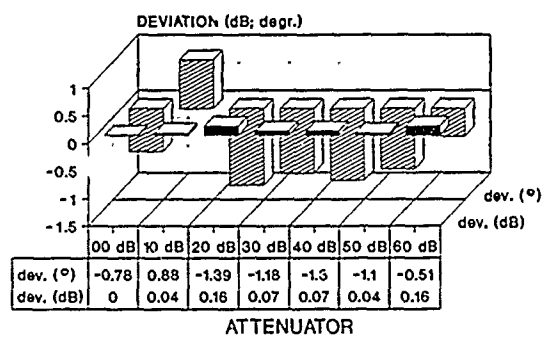
The desired accuracy is attained for a dynamic range greater than 50 dB. These results are similar to those found in chapter 4 (CW measurements) for an averaging factor of 400. When measuring in Fast-CW-mode, the time between two measurements will be  $4 \times 286 \mu\text{s} = 1.14 \text{ ms}$ , whereas with internal triggering and an averaging factor of 400 this time would be more than  $400 \times 200 \mu\text{s} = 80 \text{ ms}$  (Fast-CW-mode cannot be used with internal triggering [12, p.24]). In the low-PRF measurement configuration no averaging is applied.

The absolute amplitude and phase deviations compared with CW measurements of a CW signal are minimal (see figure 22) and less than those obtained with CW measurements of pulsed signals (see appendix B and C).

# AMPL. & PHASE DEVIATIONS

externally triggered measurements

dev. = CW-value - Pulsed-value



source power. 9dBm

Fig. 22: Amplitude and phase deviations

## 7 DISCUSSION

A way has been found to measure within milliseconds low-PRF pulsed-RF signals - as long as one is not interested in pulse profile measurements - as if it are CW signals with a 'standard' HP 8510B vector network analyzer. In this measurement method the network analyzer is externally triggered and used in Fast-CW-mode. In the measurement configuration the use of a frequency convertor instead of a test set is recommended. The measurement specifications for measuring the PHARUS pulsed-RF signal (carrier: 5.3 GHz; PRF: 3.5 kHz; pulse width: 12.8  $\mu$ s) attained are:

- Dynamic range : 50 dB;
- ampl. accuracy :  $\pm 0.10$  dB;
- phase accuracy :  $\pm 1.0^\circ$ ;
- measurement time : 1.14 ms.

During measurements a good synchronization of pulse signal and trigger signal is of paramount importance.

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- [13] Hezewijk, J.G. van: *"Performance of Wiltron 360 Network Analyzer With Pulsed Test set"*,  
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A handwritten signature in cursive script, appearing to read 'G.A. van der Spek', written over a horizontal line.

ir. G.A. van der Spek  
(Group Leader)

A handwritten signature in cursive script, appearing to read 'H.J. Visser', written over a horizontal line.

ir. H.J. Visser  
(Author)

## RAMP SWEEP MODE MEASUREMENT; MEASUREMENT TIMES

The measurement configuration is shown in figure A1.

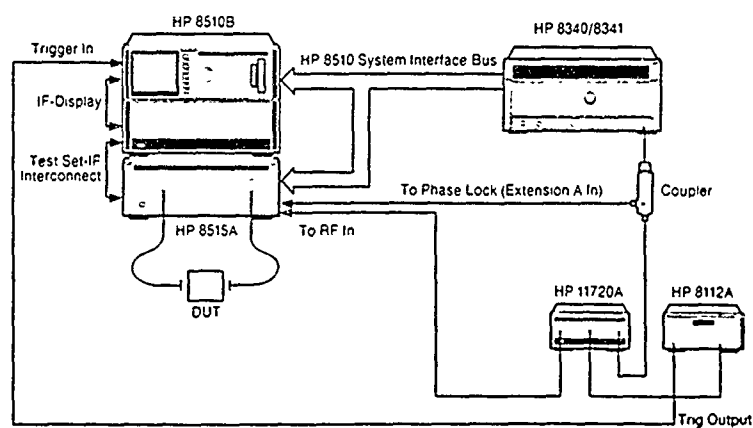


Fig. A1: Ramp sweep mode measurement configuration

The used parameters are:

- Carrier frequency : 5.3 GHz;
- pulse repetition frequency : 3.5 kHz;
- pulse width : 12.8  $\mu$ s;
- source power : -5 dBm;
- average factor : 1.

The times measured are:

- 51 points : 0.52 s/measurement;
- 101 points : 0.55 s/measurement;
- 201 points : 0.56 s/measurement.

# INTERNALLY TRIGGERED MEASUREMENTS IN A CW MEASUREMENT CONFIGURATION; CW REFERENCE SIGNAL

The measurement configuration is shown in figure B1.

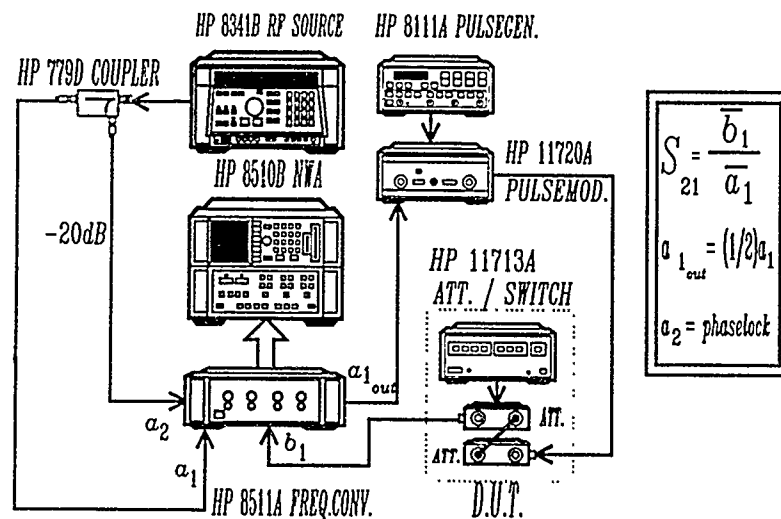


Fig. B1: Internally triggered measurement configuration;  
CW reference signal

The used parameters are:

- Carrier frequency : 5.3 GHz;
- pulse repetition frequency : 3.5 kHz;
- pulse width : 12.8  $\mu$ s;
- source power : 9 dBm.

The measurement results are stated in table B1.

Table B1: Results internally triggered measurements;  
CW reference signal

Attenuator	Average factor	Attenuation (dB)	Phaseshift (°)
3 dB	100	$-2.97 \pm 0.4$	$-36.62 \pm 0.8$
	400	$-3.01 \pm 0.4$	$-36.62 \pm 0.3$
	2000	$-3.01 \pm 0.4$	$-36.52 \pm 0.15$
10 dB	100	$-9.83 \pm 0.4$	$-7.42 \pm 0.8$
	400	$-9.86 \pm 0.05$	$-7.42 \pm 0.4$
	2000	$-9.86 \pm 0.02$	$-7.32 \pm 0.2$
20 dB	100	$-20.03 \pm 0.5$	$-12.78 \pm 0.9$
	400	$-20.02 \pm 0.05$	$-12.78 \pm 0.9$
	2000	$-20.02 \pm 0.02$	$-12.68 \pm 0.2$
30 dB	100	$-30.13 \pm 0.5$	$-4.48 \pm 0.9$
	400	$-30.13 \pm 0.05$	$-4.48 \pm 0.4$
	2000	$-30.13 \pm 0.02$	$-4.48 \pm 0.2$
33 dB	100	$-33.33 \pm 0.5$	$-32.42 \pm 1$
	400	$-33.33 \pm 0.05$	$-32.42 \pm 0.5$
	2000	$-33.33 \pm 0.02$	$-32.42 \pm 0.2$
40 dB	100	$-44.23 \pm 0.6$	$-37.62 \pm 2$
	400	$-44.28 \pm 0.1$	$-37.62 \pm 1$
	2000	$-44.28 \pm 0.04$	$-37.52 \pm 0.5$
50 dB	100	$-51.23 \pm 0.8$	$-5.62 \pm 3$
	400	$-51.23 \pm 0.2$	$-5.62 \pm 1.5$
	2000	$-51.21 \pm 0.08$	$-5.62 \pm 0.7$
60 dB	100	$-61.33 \pm 1.5$	$+25.88 \pm 9$
	400	$-61.43 \pm 0.8$	$+25.88 \pm 9$
	2000	$-61.53 \pm 0.3$	$+25.88 \pm 9$

Table B2 gives amplitude- and phase deviations from measurements of a non-pulsed 5.3 GHz signal (deviation = value CW-measurement - value pulsed measurement).

Table B2: Amplitude- and phase deviations

Attenuator	Attenuation CW (dB)	Attenuation Pulsed (dB)	Phase CW (°)	Phase Pulsed (°)	Amplitude Deviation (dB)	Phase Deviation (°)
3 dB	- 2.98	- 2.97 ± 0.40	-37.44 ± 0.05	-36.62 ± 0.80	- 0.01	- 0.82
10 dB	- 9.89	- 9.83 ± 0.40	- 8.55 ± 0.05	- 7.42 ± 0.80	- 0.06	- 1.13
20 dB	-20.14	-20.03 ± 0.50	+13.76 ± 0.05	+12.78 ± 0.90	- 0.11	+ 0.98
30 dB	-30.20 ± 0.010	-30.13 ± 0.50	+ 5.24 ± 0.10	+ 4.48 ± 0.90	- 0.070	- 0.76
33 dB	-33.29 ± 0.020	-33.33 ± 0.50	-31.55 ± 0.10	-32.42 ± 1.0	+ 0.040	+ 0.87
43 dB	-43.92 ± 0.050	-44.23 ± 0.60	-38.60 ± 0.40	-37.62 ± 2.0	+ 0.31	- 0.98
50 dB	-50.60 ± 0.10	-51.23 ± 0.80	- 9.20 ± 0.30	- 5.62 ± 3.0	+ 0.63	- 3.58
60 dB	-60.50 ± 0.35	-61.33 ± 1.5	+16.70 ± 2.0	+25.88 ± 9.0	+ 0.83	- 9.18
70 dB	-70.40 ± 1.0	not measured	+ 6.20 ± 5.0	not measured	-	-

INTERNALLY TRIGGERED MEASUREMENTS IN A CW MEASUREMENT CONFIGURATION;  
PULSED-RF REFERENCE SIGNAL

The measurement configuration is shown in figure C1.

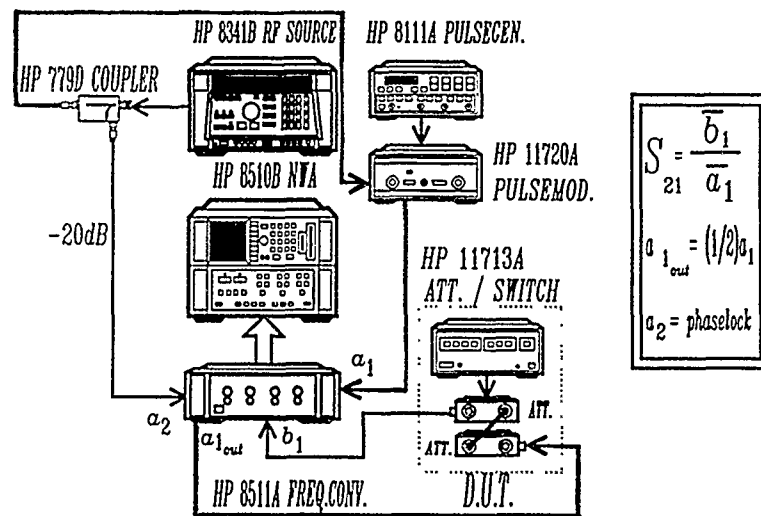


Fig. C1: Internally triggered measurement configuration;  
pulsed-RF reference signal

The used parameters are:

- Carrier frequency : 5.3 GHz;
- pulse repetition frequency : 3.5 kHz;
- pulse width : 12.8  $\mu$ s;
- source power : 9 dBm.

The measurement results are stated in table C1.

Table C1: Results internally triggered measurements;  
pulsed-RF reference signal

Attenuator	Average factor	Attenuation (dB)	Phaseshift (°)
3 dB	100	$-2.79 \pm 0.3$	$-35.98 \pm 0.8$
	400	$-2.81 \pm 0.1$	$-35.53 \pm 0.3$
	2000	$-2.82 \pm 0.025$	$-35.06 \pm 0.15$
10 dB	100	$-9.80 \pm 0.4$	$-5.90 \pm 0.8$
	400	$-9.85 \pm 0.1$	$-5.50 \pm 0.4$
	2000	$-9.85 \pm 0.03$	$-5.30 \pm 0.2$
20 dB	100	$-20.10 \pm 0.4$	$+16.60 \pm 0.8$
	400	$-20.10 \pm 0.1$	$+16.70 \pm 0.4$
	2000	$-20.09 \pm 0.03$	$+16.90 \pm 0.2$
30 dB	100	$-30.20 \pm 0.5$	$+8.30 \pm 1$
	400	$-30.18 \pm 0.1$	$+8.60 \pm 0.5$
	2000	$-30.15 \pm 0.03$	$+8.60 \pm 0.2$
33 dB	100	$-33.10 \pm 0.5$	$-27.60 \pm 1$
	400	$-33.15 \pm 0.1$	$-27.60 \pm 0.5$
	2000	$-33.15 \pm 0.03$	$-27.60 \pm 0.2$
43 dB	100	$-43.90 \pm 0.6$	$-34.30 \pm 2$
	400	$-43.90 \pm 0.2$	$-34.30 \pm 0.8$
	2000	$-44.00 \pm 0.05$	$-34.05 \pm 0.4$
50 dB	100	$-50.60 \pm 0.7$	$-4.00 \pm 3$
	400	$-50.60 \pm 0.3$	$-4.00 \pm 1.5$
	2000	$-50.70 \pm 0.1$	$-4.00 \pm 0.8$
60 dB	100	$-60.30 \pm 1.5$	$+19.00 \pm 9$
	400	$-60.30 \pm 0.8$	$+20.00 \pm 5$
	2000	$-60.30 \pm 0.3$	$+21.00 \pm 2$

Table C2 gives amplitude- and phase deviations from measurements of a non-pulsed 5.3 GHz CW signal (deviation = value CW measurement - value pulsed measurement)

Table C2: Amplitude- and phase deviations

Attenuator	Attenuation CW (dB)	Attenuation Pulsed (dB)	Phase CW (°)	Phase Pulsed (°)	Amplitude Deviation (dB)	Phase Deviation (°)
3 dB	- 2.98	- 2.97 ± 0.30	-37.44 ± 0.05	-35.98 ± 0.80	- 0.19	- 1.46
10 dB	- 9.89	- 9.80 ± 0.40	- 8.55 ± 0.05	- 5.90 ± 0.80	- 0.09	- 2.65
20 dB	-20.14	-20.10 ± 0.40	+13.76 ± 0.05	+16.60 ± 0.80	- 0.04	- 2.84
30 dB	-30.20 ± 0.010	-30.20 ± 0.50	+ 5.24 ± 0.10	+ 8.30 ± 1.0	0	- 3.06
33 dB	-33.29 ± 0.020	-33.10 ± 0.50	-31.55 ± 0.10	-27.60 ± 1.0	- 0.19	- 3.95
43 dB	-43.92 ± 0.050	-43.90 ± 0.60	-38.60 ± 0.40	-34.30 ± 2.0	- 0.02	- 4.30
50 dB	-50.60 ± 0.10	-50.60 ± 0.70	- 9.20 ± 0.30	- 4.0 ± 3.0	0	- 5.20
60 dB	-60.50 ± 0.35	-60.30 ± 1.5	+16.70 ± 2.0	+19.0 ± 9.0	- 0.20	- 2.30
70 dB	-70.40 ± 1.0	- 69.0 ± 4.0	+ 6.20 ± 5.0	+ 20.0 ± 30	- 1.4	-13.80

## WILTRON 360 MEASUREMENT; NON PULSED NWA

The measurement configuration is shown in figure D1.

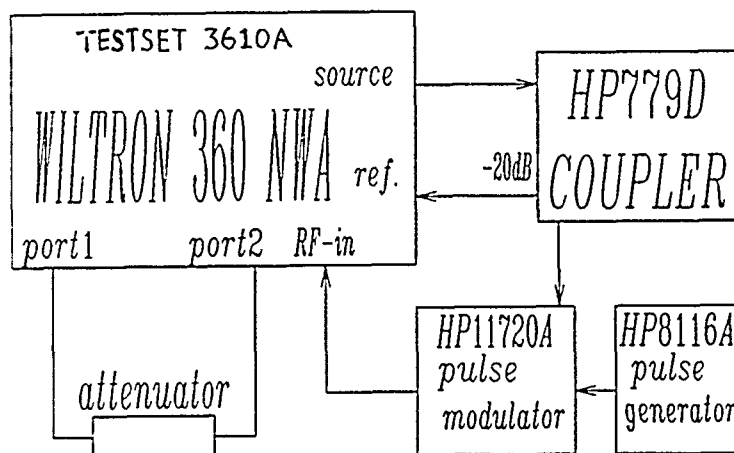


Fig. D1: Internally triggered measurement configuration Wiltron 360; pulsed-RF reference signal

The used parameters are:

- |                              |   |               |
|------------------------------|---|---------------|
| - Carrier frequency          | : | 5.3 GHz;      |
| - pulse repetition frequency | : | 3.5 kHz;      |
| - pulse width                | : | 12.8 $\mu$ s; |
| - source power               | : | 5 dBm;        |
| - average factor             | : | 100.          |

The measurement results are stated in table D1.

Table D1: Results internally triggered measurements;  
pulsed-RF reference signal

Attenuator	IF bandwidth	Attenuation (dB)	Phaseshift ( $^{\circ}$ )
3dB	N	X	X
NARDA	R	X	X
01594	M	-2.4	-109.4 $\pm$ 0.1
10dB	N	X	X
HP	R	X	X
6921	M	-9.5 $\pm$ 0.1	-109.6 $\pm$ 0.2
20dB	N	X	X
NARDA	R	X	X
01734	M	-19.8 $\pm$ 0.1	-96 $\pm$ 1
30dB	N	X	X
NARDA &	R	X	X
HP	M	-29.5 $\pm$ 0.5	+148 $\pm$ 2
33dB	N	X	X
NARDA &	R	X	X
HP	M	-32.5 $\pm$ 0.5	+39 $\pm$ 4
43dB	N	X	X
NARDA &	R	X	X
HP	M	-42 $\pm$ 1	-62 $\pm$ 8

## WILTRON 360 MEASUREMENTS; PULSED NWA

The measurement configuration is given in figure E1.

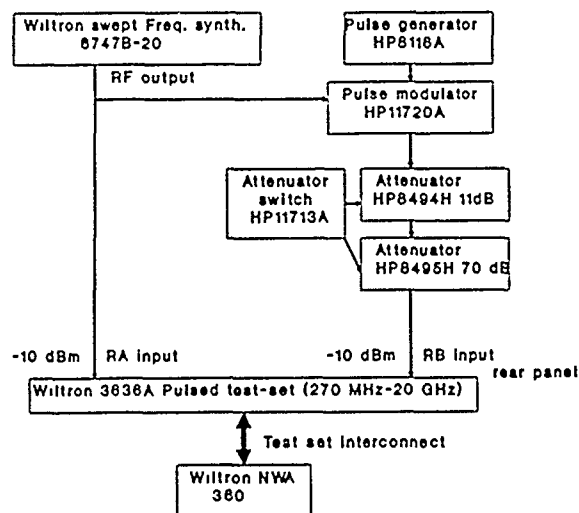


Fig E1: Set-up for pulsed measurements

A CW reference (necessary for phase locking the system) is put at the input of a mixer and the pulsed test signal is put at the input of the other mixer at the back of the testset. The internal couplers of the testset are not used. The signal is modulated externally with a generator and a modulator. The pulse cannot be profiled now; only the transmission coefficient can be determined. The measurement results are shown in table E1.

Table E1: Results of pulsed measurements

Pulsed signal (PRF=5.3 GHz, T= 12.8 $\mu$ sec) Normal bandwidth, no averages				
Atten(dB)	Amplitude(dB)		Phase(degrees)	
	mean	fluct.( $\pm$ )	mean	fluct.( $\pm$ )
0	+0.01	0.01	0.1	0.20
10	-10.04	0.02	-8.3	0.25
20	-19.91	0.04	-4.0	0.30
30	-29.99	0.10	-12.0	0.70
40	-41.00	0.35	-1.0	2.5
50	-51.00	1.0	-8.0	6.0
60	-61.00	3.0	0.0	20.0

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15. ABSTRACT THIS REPORT DESCRIBES HOW A HEWLETT PACKARD HP 8510B VECTOR NETWORK ANALYZER WITH A NON-PULSED TESTSET CAN BE USED FOR MEASURING PULSED-RF SIGNALS WITH A LOW PULSE REPETITION FREQUENCY WITHIN MILLISECONDS, BY MAKING USE OF THE EXTERNAL TRIGGER FACILITY THIS MEASUREMENT CONFIGURATION IS DERIVED AFTER AN ANALYSIS OF THE SIGNAL FLOW THROUGH THE RECEIVER OF THE NETWORK ANALYZER. ALTHOUGH THE MEASUREMENT METHOD IS DERIVED FOR A SPECIFIC PULSED-RF SIGNAL (CARRIER: 5.3 GHZ; PULSE REPETITION FREQUENCY: 3.5 KHZ; PULSE WIDTH: 12.8 μS) AND MEANT FOR USE IN A NEAR-FIELD MEASUREMENT FACILITY, ITS APPLICABILITY IS MORE GENERAL. IT WILL NOT BE POSSIBLE TO PERFORM PULSE PROFILE MEASUREMENTS. THE DESIRED AND ATTAINED MEASUREMENT SPECIFICATIONS ARE: <table style="width: 100%; margin-top: 10px;"><thead><tr><th></th><th style="text-align: center;">Desired specifications</th><th style="text-align: center;">Attained specifications:</th></tr></thead><tbody><tr><td>DYNAMIC RANGE</td><td style="text-align: center;">≥ 40 DB,</td><td style="text-align: center;">50 DB,</td></tr><tr><td>AMPL. ACCURACY</td><td style="text-align: center;">± 0.3 DB,</td><td style="text-align: center;">± 0.1 DB,</td></tr><tr><td>PHASE ACCURACY</td><td style="text-align: center;">± 3.0°</td><td style="text-align: center;">± 1.0°;</td></tr><tr><td>MEASUREMENT TIME</td><td style="text-align: center;">&lt; 10 MS</td><td style="text-align: center;">1.14 MS.</td></tr></tbody></table>				Desired specifications	Attained specifications:	DYNAMIC RANGE	≥ 40 DB,	50 DB,	AMPL. ACCURACY	± 0.3 DB,	± 0.1 DB,	PHASE ACCURACY	± 3.0°	± 1.0°;	MEASUREMENT TIME	< 10 MS	1.14 MS.
	Desired specifications	Attained specifications:															
DYNAMIC RANGE	≥ 40 DB,	50 DB,															
AMPL. ACCURACY	± 0.3 DB,	± 0.1 DB,															
PHASE ACCURACY	± 3.0°	± 1.0°;															
MEASUREMENT TIME	< 10 MS	1.14 MS.															
16. DESCRIPTORS PULSE CIRCUITS SHORT DURATION PULSES ANTENNA RADIATION PATTERNS	IDENTIFIERS NETWORK ANALYZER NEAR FIELD MEASUREMENT																
17a. SECURITY CLASSIFICATION (OF REPORT)  UNCLASSIFIED	17b. SECURITY CLASSIFICATION (OF PAGE)  UNCLASSIFIED	17c. SECURITY CLASSIFICATION (OF ABSTRACT)  UNCLASSIFIED															
18. DISTRIBUTION/AVAILABILITY STATEMENT  UNLIMITED AVAILABILITY	17d. SECURITY CLASSIFICATION (OF TITLES)  UNCLASSIFIED																

UNCLASSIFIED